UV-C Decontamination of Filtering Facepiece Respirators Contaminated with MS2 Bacteriophage

Edward M. Fisher and Ronald E. Shaffer

NIOSH/NPPTL, Pittsburgh, PA

Objective

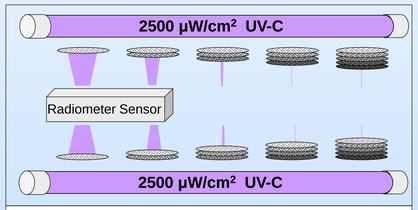
To examine the effectiveness of Ultraviolet-C irradiation (UV-C, 254 nm) as a method for filtering facepiece respirator (FFR) decontamination.

Introduction

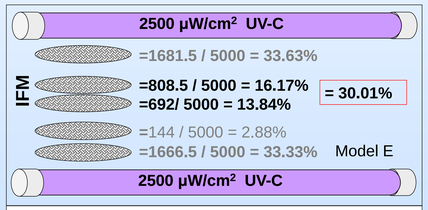
NIOSH-certified N95 filtering facepiece respirators (FFRs) are recommended for protection against the airborne transmission of infectious microorganisms. FFR supplies may not be adequate to match the increased demand during a pandemic crisis. Reuse of disposable FFRs after decontamination has been suggested as a possible strategy to help maintain FFR supplies; however, there are no approved methods for FFR decontamination. This research examines the use of UV-C irradiation for FFR decontamination and describes a method to assess model specific FFR decontamination likelihood based on effective doses to the Internal Filtering Medium (IFM).

Experimental Approach

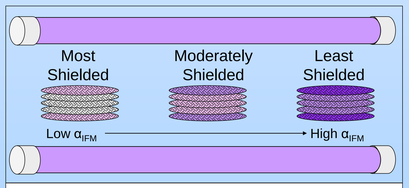
Step 1:
Excise circular coupons (5 cm^2) and separate layers



Step 2:
Measure UVC transmission through the layers of each FFR model in 2 directions



Step 3:
Calculate α_{IFM} (% of the surface UV-C that interacts with the IFM) for each model



Step 4:
Place FFR models into shielded categories by α_{IFM} values

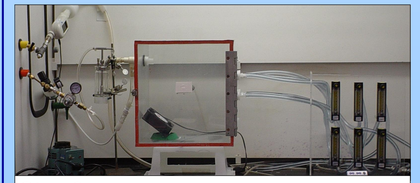
Calculated IFM Dose (J/m^2)

Shielded Category	Model	Time (min) 1	2	4	10
Most	A	4	8	15	38
Moderately	C	92	183	367	917
Least	E	471	941	1883	4707

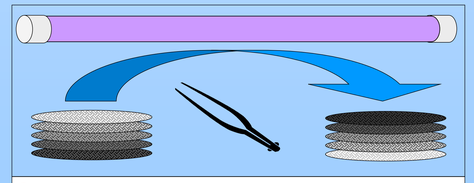
Calculated Exposure Times (min)

Shielded Category	Model	Dose (J/m^2) 300	1000	3000
Most	B	9.6	31.9	95.6
Moderately	D	2.5	8.2	24.5
Least	F	0.7	2.3	6.9

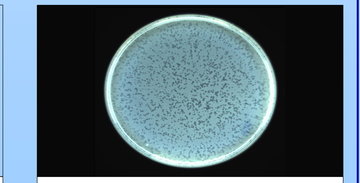
Step 5:
Select UV-C decontamination test parameters using α_{IFM} to calculate doses and exposure times. *Dose = Intensity • Time • α_{IFM}* *Time = Dose/(Intensity • α_{IFM})*



Step 6:
Load 6 coupons simultaneously with MS2 aerosol (droplet nuclei)



Step 7:
Expose contaminated coupons to UV-C for predetermined exposure time from each side



Step 8:
Recover MS2 and enumerate with plaque assay

Results

Table 1. α-values of the composite layers of FFRs and categorization by α_{IFM}

FFR	A	B	C	D	E	F
Layer 1	49.98	48.9	43.55	36.21	33.63	36.86
Layer 2	0.05	1.09	5.25	4.61	16.17	7.89
Layer 3	0.05	1.09	0.86	8.5	13.84	9.42
Layer 4	0.16	49.02	50.33	50.67	2.88	21.96
Layer 5	49.76	NA	NA	NA	33.33	23.44
Shielded category	**Most**		**Moderately**		**Least**	
α_{IFM}	**0.25**	**2.18**	**6.11**	**8.5**	**30.01**	**31.38**

- All values in percentage
- Red boxes indicate layers designated as IFM
- Sum of filtering medium may not equal α_{IFM} due to rounding errors

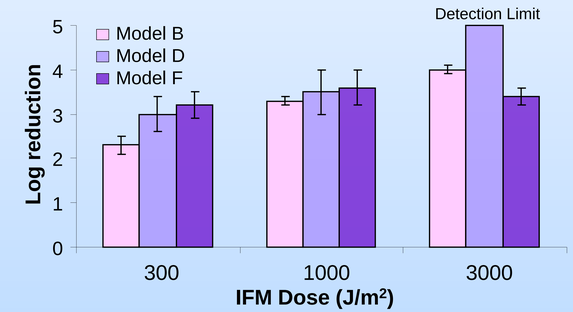


Fig 2. Log reductions of MS2 on coupons excised from FFRs representing each shielded category. Contaminated coupons were exposed to model specific (α_{IFM} calculated) UV-C doses of 300, 1000 and 3000 J/m^2. Error bars represent 1 standard deviation range for quadruplicate coupons.

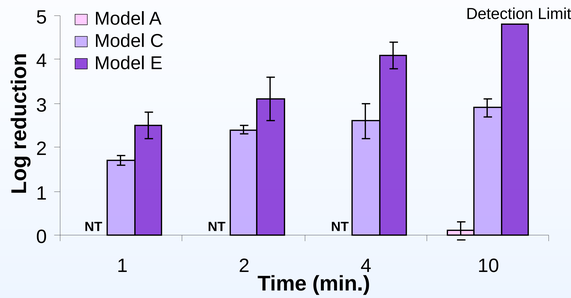


Fig 1. Log reductions of MS2 on coupons excised from FFRs representing each shielded category. Contaminated coupons were exposed to UV-C for 1, 2, 4, and 10 minutes. Error bars represent 1 standard deviation range for quadruplicate coupons. (NT = not tested)

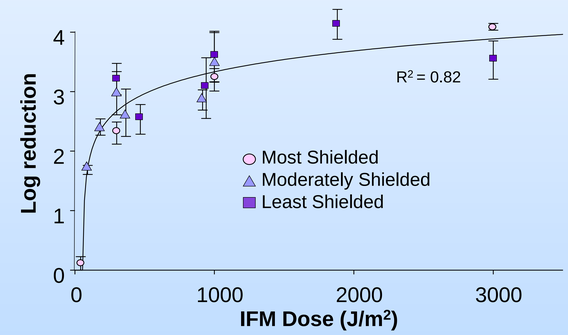


Fig 3. Dose response relationship of MS2 inactivation of FFR coupons exposed to UV-C doses determined for internal filtering medium for respirators from all 3 shielded categories. Error bars represent 1 standard deviation range for quadruplicate coupons.

Conclusions

- UV-C transmits through FFR materials.
- Log reduction was shown to be a function of model-specific UV-C doses based on α_{IFM} values.
- Model specific UV-C transmission can be used to determine FFR decontamination likelihood.
- The methodology developed in this study may be applied to other multilayered porous materials.
- Future research is needed before UV-C decontamination of FFRs can be implemented

Future Directions

- Test UV-C efficacy for other microorganisms that are specific to respiratory illnesses.
- Determine the effect of residues (respiratory secretions) on the transmission of UV-C through FFRs.
- Use intact FFRs to discern the effects of FFR shape on UVC decontamination.
- Test other FFR materials (straps and nose pieces)
- Use multiple UV-C sources to increase decontamination efficacy.

Disclaimer: The findings and conclusions in this poster have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

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